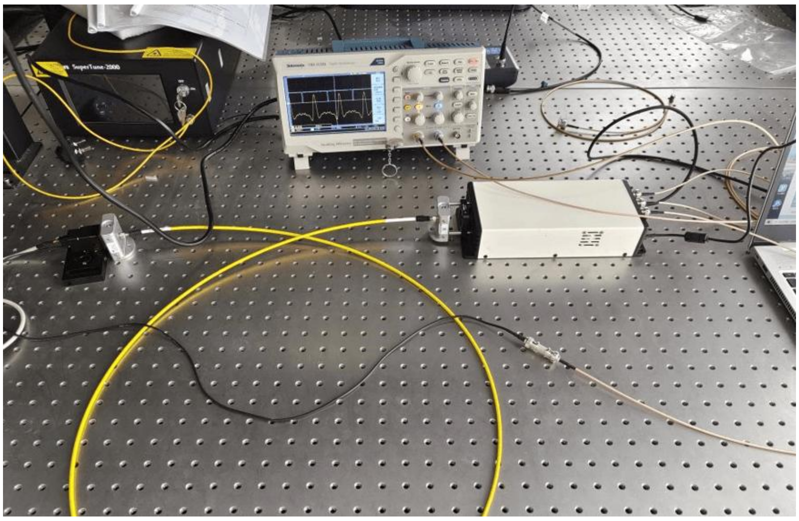
7.4um QCL combined with hollow core fiber gas absorption cell analysis system (experimental analysis of H2O, dihydrogen monoxide and water in the air)



- ## Product Description

7.4um low-power benchtop DFB-QCL mid-infrared quantum cascade laser is a domestically advanced ultra-low-power QCL DFB laser developed by Idealphotonics in the first half of 2018. The tunable range exceeds 100nm, and the output power is greater than 20mw to meet the industrial needs of customers testing gas sensors. Our laser collimated output has stable output power and high temperature and wavelength stability, which is several orders of magnitude higher than the stability of traditional high-power quantum cascade lasers. It provides an excellent test light source for our mid-infrared test customers.

Product features

Quantum cascade laser; hollow-core fiber gas absorption cell; ppb-level detection sensitivity; environmental interference immunity design; modular integrated system.

Part Number

MP-QCL-7400-DFB-5-H2O-S

Application area

Atmospheric water vapor monitoring | Industrial process humidity control | Environmental science research | High-precision meteorological observation | Semiconductor process gas analysis

Core parameters

Wavelength range	Optical path
7.4μm	0.1-5m

General Parameters

I. Theoretical basis

1. Beer-Lambert law

When a laser beam passes through a measured gas with a concentration of C, when the wavelength of the laser is the same as the center frequency of a certain absorption spectrum line of the measured gas, the gas molecules will absorb photons and transition to a high energy level, which is manifested as the attenuation of the laser light intensity in the gas absorption band

2. Wavelength modulation spectroscopy technology

A) Tuning characteristics of lasers

DFB lasers have good monochromaticity, narrow linewidth characteristics and frequency tuning characteristics. DFB lasers can effectively avoid cross interference from other background gases, making the detection system have better measurement accuracy. Therefore, they are widely used in gas detection.

B) Harmonic detection theory

By adding a high-frequency sinusoidal voltage signal to the laser drive voltage, the current is changed, so that the output frequency also changes according to the sinusoidal law. By adding a sawtooth voltage to the laser drive, the output wavelength is scanned on both sides of the gas absorption peak, and the harmonic signal is modulated and demodulated using a phase-locked amplifier to measure the gas concentration.

3. Principles of absorption spectrum selection

When performing gas detection, the selection of absorption spectrum is very critical, and the following aspects should be considered

(1) The gas should have a strong absorption peak at the selected spectrum line,

(2) The laser light source technology corresponding to the spectrum line wavelength should be relatively mature

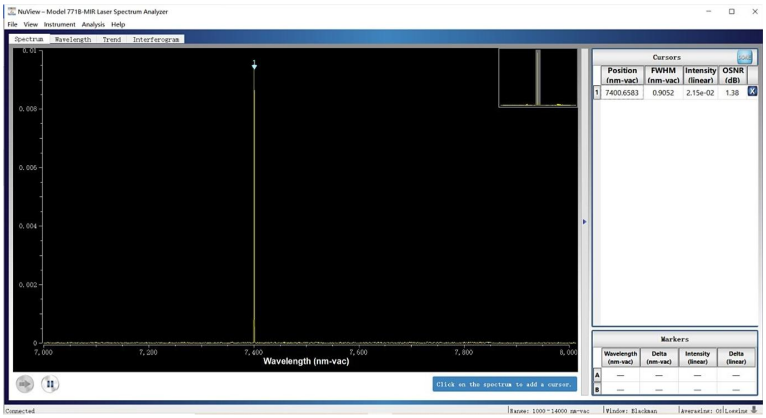
(3) There is no interference from background gas absorption at the selected absorption spectrum line, or the absorption is relatively weak and can be ignored

Experimental Instruments

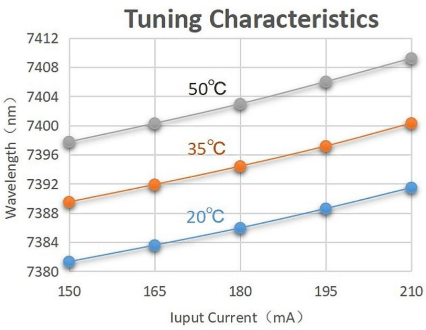
1. 7.4um low power desktop DFB-QCL mid-infrared quantum cascade laser

QCL7400 - 7.4um low-power desktop DFB-QCL mid-infrared quantum cascade laser is the first low-power QCL DFB laser in China developed by Idealphotonics in the first half of 2018. It has a tunable range of over 100nm and an output power of more than 25mw to meet customers' industrial needs such as testing gas sensors.

Our laser collimated output has stable output power and extremely high temperature and wavelength stability, which is several orders of magnitude higher than the stability of traditional high-power quantum cascade lasers. It provides the best test light source for our mid-infrared test customers.

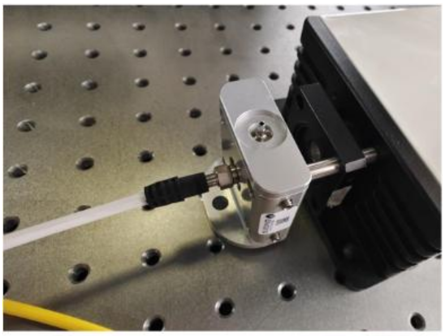


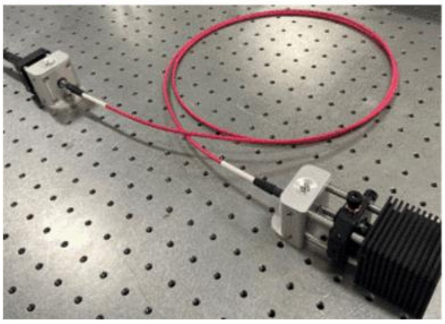
Spectrogram



Wavelength temperature current tuning curve

2. Hollow fiber gas absorption cell

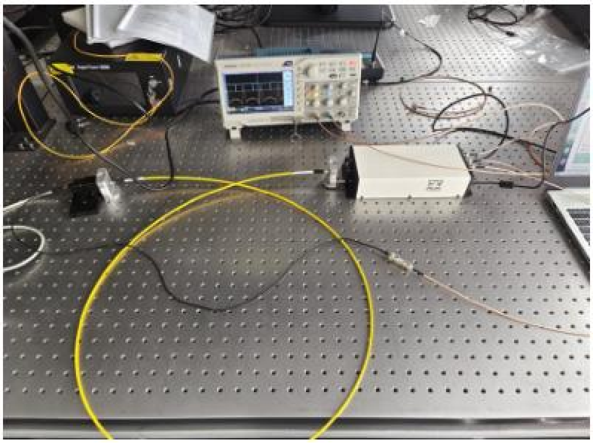




The hollow fiber gas absorption cell includes an optical window, a fiber port, and a gas port. With two of these modules, you can transform a hollow fiber into a benchtop gas absorption cell for absorption spectroscopy or reference wavelength applications by simply replacing the fiber with a different path length.

3. 2-15um mercury cadmium telluride (MCT) mid-infrared photodetector with amplifier and TEC

The detector is a thermoelectrically cooled photoconductive HgCdTe (mercury cadmium telluride, MCT) detector. This material is sensitive to light in the mid-infrared spectral range of 2.0 to 15µm. The temperature of the detector element is controlled at -30°C by a thermistor feedback circuit using a TEC, thereby minimizing the effects of thermal changes on the output signal. For best results, we recommend connecting the output cable (not included) with a 50 ohm termination. Since the detector is AC coupled, it requires a pulsed or chopped input signal. AC coupled detectors will not see an unchopped DC signal because they are sensitive only to changes in intensity, not to the absolute value of the intensity.This experiment uses a 7.4um QCL laser combined with a hollow fiber gas absorption cell to test H2O gas in the air.



System Diagram

Operation steps：

1. Install the 7.4um QCL laser and collimate the output to one end of the hollow-core fiber chamber

2. Connect the other end of the hollow-core fiber chamber to the MCT detector

3. Use a BNC to SMA cable to connect the detector to the PREAMP preamplifier end of the 7.4um QCL laser

4. Use a BNC-BNC cable to connect the oscilloscope to the DACOUT analog output end of the 7.4um QCL laser

5. Use a BNC-BNC cable to connect the oscilloscope to the TRIG OUT trigger end of the 7.4um QCL laser

6. Turn on the laser and detector

7. Adjust the software parameters and observe the second harmonic signal

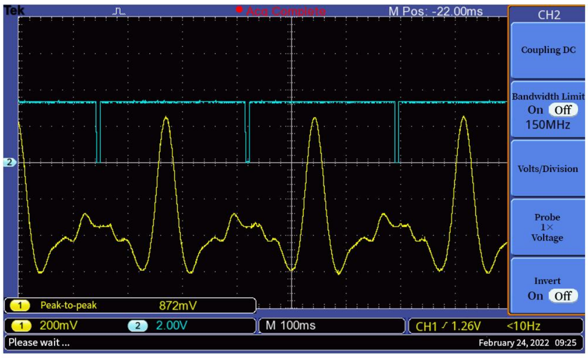
waveform, amplitude and other information on the oscilloscope

Process analysis:

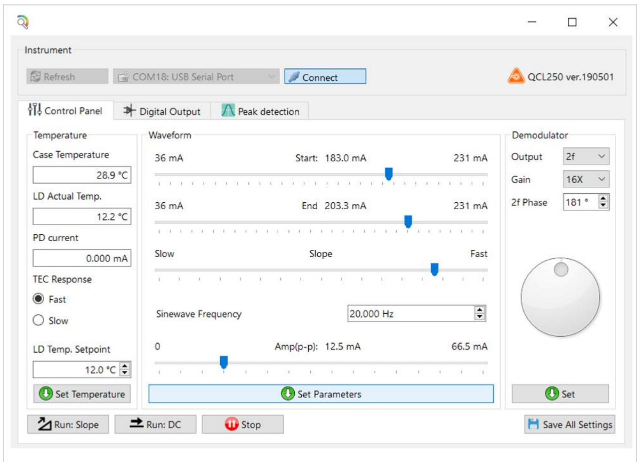
The control software on the computer is used to adjust the current and temperature to tune the wavelength, so that the laser can scan a certain wavelength range and the output wavelength covers the absorption peak of the gas. The phase-locked amplifier provides a high-frequency sinusoidal modulation signal to make the laser output frequency sinusoidally modulated. The light emitted by the laser passes through the gas absorption cell and enters the preamplifier circuit at the PREAMP end through the detector. It is then modulated and demodulated by the phase-locked amplifier and sent to the oscilloscope channel 2 through the DAC OUT analog output end to display the second harmonic signal. During the whole process, we adjusted various parameters in the software and observed the output waveform at the same time to optimize the output waveform.

Experimental result

1. The second harmonic waveform and modulation parameters are as follows:

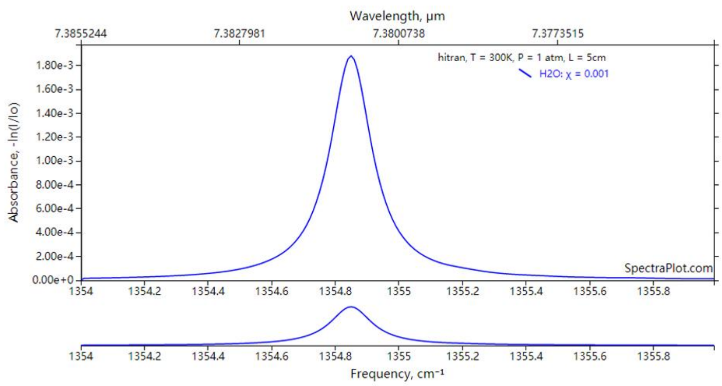


Second Harmonic



Wavelength temperature current tuning curve

2. Verification and analysis: By querying the Hitran database, the absorption lines in the wave number range of 1354cm-1 to 1356cm-1 are as follows:



The absorption peak wavelength is about 7.381um. By comparing the second harmonic amplitude information, it is consistent with the database, thus verifying that it is H_2O gas.

3. Experimental conclusion: Through testing, we found that when using this test system to analyze H_2O gas in the air, the second harmonic amplitude can reach 872mV, indicating that this test system has high accuracy.

#	Name	Description	Number
1	7.4um mid-infrared quantum cascade laser	Peak operating wavelength 7.4um, output power 5mW, spectrum width<1MHz, output isolation 30dB, desktop size 340(L)x240(W)x100(H)mm	1
2	Hollow fiber gas absorption cell	Extremely simple and robust alignment, Wavelength range: UV to LWIR, Pathlength range: 0.1 to 5m, Low sample volume:<10mL, Compact size; Flexible layout	1
3	2-15um Mercury Cadmium Telluride (MCT) Mid-Infrared Photodetector	Response wavelength range 2-15um, photosensitive surface size 2x2mm, working bandwidth 10Hz-14MHz	1
4	USB flash drive	Including operating software, product manual	1